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Original research

The Impact of a Gap Balancing or Measured Resection Surgical Technique on Posterior Condylar Offset and Patient-Reported Outcome Measures

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ABSTRACT

Background: To increase total knee arthroplasty procedure satisfaction, surgeons are exploring improvements in surgical technique. The impact of gap balancing or measured resection approach on posterior condylar offset (PCO) is not well understood.
Methods: We reviewed the clinical and radiographic results of 498 unilateral posterior stabilized total knee arthroplasties. Radiographs were assessed to measure the primary endpoints of anterior-posterior width, PCO, and anterior condylar offset. Clinical outcome measures were used to assess patient improvement measures. Multiple linear regression analyses were performed to determine the clinical factors related to our primary endpoints.
Results: No significant difference was observed between groups in anterior-posterior width ($P = .24$) and PCO ($P = .78$). Significant positive correlations were observed between postoperative PCO and knee range of motion ($r = 0.12$, $P = .04$) and total Knee Society Scores ($r = 0.14$, $P = .02$).
Conclusion: No impact of surgical technique on PCO was observed. Correlations were observed between postoperative PCO and the functional subscore and total Knee Society Score. All patients reported clinical improvements at 1 year postoperatively.

Introduction

End-stage osteoarthritis (OA) of the knee joint recalcitrant to medical management can be treated with a total knee arthroplasty (TKA). The physical impairments which accompany end-stage OA can contribute to large declines in patient functioning and quality of life [1]. As such, a primary functional outcome measure after a TKA is postoperative maximum knee flexion. It is well understood that after TKA, the objective and subjective functional outcomes do not equal those of the normal knee. In fact, it has been reported that up to 1.3% of patients report restrictive knee movement after TKA [2,3].

Maximum knee flexion or range of motion (ROM) postoperatively can be affected by a number of factors, including but not limited to, body mass index, quadricep length, degree of tightness of the joint capsule, whether a gap balancing (GB) or measured resection (MR) surgical technique was used, or features inherent to implant design [2,4]. Posterior condylar offset (PCO) after a TKA is determined by surgical technique, the amount of bone resected, and the joint prosthesis implanted. There is controversy in the literature as to whether PCO impacts knee flexion after TKA [2,4-7]. Some studies report correlation between the degree of offset and joint ROM, but others report discordance between the 2 measures [8]. Furthermore, randomized studies looking at the role of the posterior cruciate ligament in maximum postoperative flexion and functional outcome scores report no difference between posterior cruciate retaining (CR) and substituting implant designs [2,9].

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While there are many nuances of the TKA procedure that are debated among arthroplasty surgeons, the primary goals are well established. As dissatisfaction still remains in approximately one in every 5 patients postoperatively, many surgeons have sought improvements in surgical technique with the hopes of improving procedure satisfaction [10]. Improvements have involved changes to their soft-tissue balancing procedures, component positioning, or both [11,12]. Currently, 2 modern surgical techniques exist: GB and MR. In a GB surgical approach, soft-tissue releases are conducted before the bone resection determining the femoral component rotation [13]. While in an MR approach, bone resections are made according to predetermined anatomical landmarks, and the soft-tissue releases are conducted to subsequently balance the knee [13]. The amount of bone resected is equivalent to the thickness of the prosthesis being implanted. Various advantages and disadvantages accompany both techniques [14]. It is suggested that the GB technique is associated with greater coronal plane stability and more symmetrical flexion and extension gaps yet has an increased likelihood of joint line elevation [14-17]. The MR technique places an emphasis on natural knee anatomy but relies upon precise intraoperative determination of bony landmarks which often become disfigured during the OA disease process [18-21].

The term PCO is used to describe the amount of posterior projection of the femoral prosthesis to the tangent of the posterior femoral cortex [4,5]. This concept was popularized to further understand joint motion and the forward translation of the tibia during flexion [4]. The translation can be limiting to maximal joint flexion by posterior impingement of the tibia against the posterior surface of the femur. It is proposed that decreased PCO may be a limiting factor in postoperative flexion. The role surgical technique plays in PCO postoperatively, and subsequently knee flexion, is not well understood.

The goal of this study was two-fold. Our primary outcome was to examine the impact of surgical technique on PCO and total anterior-posterior (AP) width postoperatively with relation to the change from preoperative measures. Second, we aimed to examine the relationship between postoperative PCO and ROM and patient-reported outcome measures (PROMs). We hypothesized that there would be less change between preoperative and postoperative PCO within the MR group. Furthermore, we hypothesized that patients with greater PCO postoperatively would report larger ranges of motion and greater maximum flexion. With greater joint ROM, we hypothesized that these patients would also report greater degrees of satisfaction and functionality on their PROMs.

Material and methods

Ethics approval was obtained from the health science research ethics board (REB#:109,435). All identified patients were reviewed for inclusion and exclusions criteria by 2 independent reviewers.

All patients who received a primary TKA between August 1, 2012, and January 31, 2016, performed by 2 fellowship-trained surgeons were identified from a single institution's arthroplasty database. All patients were older than 18 years. Patients who received a Stryker Triathlon prosthesis (Stryker, Kalamazoo, MI) and were at a minimum 1-year time point after the surgery were included in the study. Patients had to have both a preoperative and 1-year postoperative radioraphs available for determination of the AP width and PCO. Five hundred and twelve patients were identified, 498 who received a posterior-sacrificing prostheses, and 14 who received a CR TKA.

Patients were grouped based on the surgical technique used for their TKA procedure, either a gap-balanced or MR technique, in an expertise approach. For the GB technique, the McBride soft-tissue tensioner was used. For the MR technique, posterior referencing instruments and cutting block were used. Relevant patient demographic information was collected, including age, body mass index, sex, surgical side, and implant design. Patient demographics are listed in Table 1.

Radiographs were reviewed from our electronic picture archiving and communication system. Radiological measurements included preoperative and postoperative PCO, AP width, and anterior condylar offset (ACO) (Fig. 1). All radiographs were measured independently by a blinded reviewer. In order to provide reliable measurements, PCO was measured according to that previously defined by Bellemans et al. [4]. Our secondary outcomes included clinician- and PROMs. We collected Short Form-12 (SF-12) scores, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores, and Knee Society Scores (KSS) from patient charts both preoperatively and postoperatively.

All data were assessed for normality using the D'Agostino and Pearson omnibus normality test. Depending on normality, demographics and baseline PROMs were compared between groups using either an unpaired t-test (parametric) or using a Mann-Whitney test (nonparametric), whereas the ratio of males:females and right:left knee were compared between groups using a Fischer exact test. Baseline and postoperative radiological measurements were compared between groups using a Mann-Whitney U statistical test. Correlational analysis was performed between PCO and knee ROM and PROMs using Pearson's correlation coefficient (r). Correlations were classified as being either weak (|0.2|-|.39|), moderate (|0.4|-|.79|), or strong (|0.8|-|1.00|). A paired t-test (parametric) or Wilcoxon matched pairs signed rank test (nonparametric) was used to compare baseline and 1-year PROMs data. Level of significance was set as $P < .05$. All statistical tests were conducted using GraphPad Prism v8.0 (GraphPad Software, La Jolla, CA).

Results

There was no significant difference in age, body mass index, sex, or operative side between the 2 surgical approach groups ($P > .05$). The MR group had significantly more patients receive a CR implant than the GB group (14 patients vs 0 patients). As such, patients who received a CR implant were excluded from study analysis. The analysis presented here on out includes only patients who received a posterior-stabilizing implant design (n = 498).

There were no significant differences between the GB and MR surgical groups at baseline with respect to AP width ($P = .70$), PCO ($P = .88$), and ACO ($P = .05$). Similarly, no significant difference was observed postoperatively between the groups in terms of AP width ($P = .24$) and PCO ($P = .78$). A significant difference preoperatively was observed between the groups with respect to ACO ($P = .04$), with the MR group reporting greater values. This significant difference was present postoperatively as well ($P = .002$). Both groups saw significant changes in posterior and ACO between the preoperative and postoperative time points ($P < .0002$). Mean measurements preoperatively and postoperatively, as well as change scores, can be found in Table 2.

As no significant difference existed between the groups' PCO postoperatively, correlations were examined between measures with the cohorts combined. Significant correlations were observed

Table 1
Patient demographics, presented as mean ± standard deviation.

Demographic	Gap balancing (n = 210)	Measured resection (n = 288)	P value
Age, y	68.5 ± 8.8	67.6 ± 10.4	.33
BMI, kg/m^2	33.0 ± 6.8	35.2 ± 14.2	.36
Sex	77 males: 133 females	105 males: 183 females	.99
Side	105 right: 105 left	149 right: 139 left	.72
Implant type	210 PS	14 CR: 274 PS	.0005

BMI, body mass index.

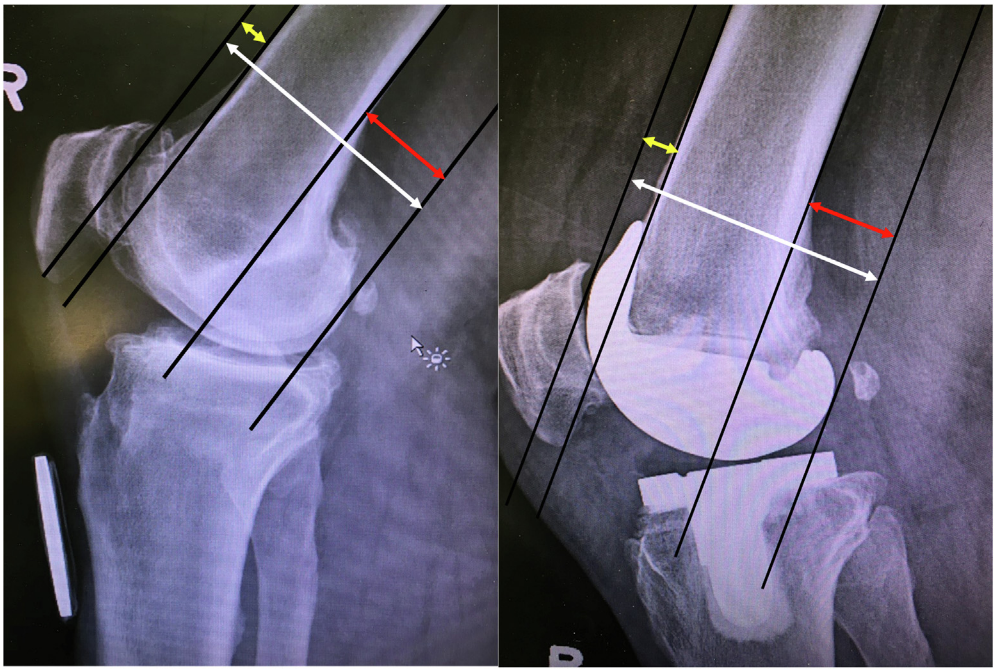

Figure 1. The method for measuring primary radiographic endpoints (yellow: ACO, red: PCO, white: AP width).

between postoperative PCO and knee ROM, with greater PCO being associated with a greater ROM (r = 0.12, *P* = .04) and total KSS score (r = 0.14, *P* = .02). Nonsignificant correlations were observed between postoperative PCO and SF-12 mental and physical components and the WOMAC total (*P* > .05). No significant correlation was observed between PCO difference and 12-month range of movement defined by the KSS flexion subscore (r = 0.07, *P* = .26).

When examining PCO change and its correlation with KSS and WOMAC subscores, no significant correlations were observed (*P* > .05). Correlations between change in PCO and WOMAC total (r = 0.06, *P* = .30) and KSS total (r = 0.05, *P* = .39) were insignificant.

No significant differences were found between the GB and MR surgical techniques in terms of PROMs at baseline. Means and standard deviations of both groups at the preoperative time point can be found in Table 3. Significant improvement (*P* < .05) was noted in both the GB surgical approach group and MR group between baseline and 1 year postoperatively in the SF-12 physical component score, WOMAC total score, and KSS total score. No significant improvement was noted in the SF-12 mental component score (*P* > .05).

A subanalysis of a component of the KSS questionnaire looking at knee ROM was conducted. No significant difference was observed between preoperative ROM between the GB and MR groups (105° ± 14.3° vs 102° ± 16.3°, *P* = .11). No significant difference in ROM was identified between the 2 groups at 1 year postoperatively (*P* = .36). Patients of both groups saw a significant improvement in ROM at the 1-year time point (*P* < .0001), with an average ROM of 120° ± 8.7° and 121° ± 7.4°, in the GB and MR groups, respectively.

Table 2
Radiological measurements, presented as mean (mm) ± standard deviation.

Group/measurement	Preoperatively	Postoperatively	Change	*P* value
GB (n = 210)				
AP width (mm)	70.6 ± 7.48	69.8 ± 4.94	−0.80	.31
PCO (mm)	28.6 ± 3.59	30.4 ± 4.02	1.80	.0002
ACO (mm)	6.91 ± 3.33	4.19 ± 2.58	−2.72	<.0001
MR (n = 274)				
AP Width (mm)	71.2 ± 6.21	70.5 ± 4.84	−0.70	.26
PCO (mm)	28.5 ± 3.98	30.5 ± 3.45	2.00	<.0001
ACO (mm)	7.36 ± 3.17	4.95 ± 2.43	−2.57	<.0001

Discussion

In the present study, the impact of a GB or a MR surgical technique on PCO was examined for patients undergoing unilateral TKA. It was demonstrated that there was no significant impact of surgical approach on postoperative PCO. Regardless of surgical approach, patients saw on average an increase in PCO and a decrease in ACO postoperatively. Theoretically, this would correlate with greater knee ROM postoperatively because of a delay of tibial impingement on the femoral surface. The correlations we observed between postoperative PCO and knee ROM and total KSS score, although significant, were weak. A study comparing postoperative PCO and knee flexion angle between CR TKA and posterior stabilized (PS) TKA reported strong correlations between measured values for CR TKAs and no correlations for PS TKAs [5]. These trends were also previously reported by Bellemans et al. [4]. As our cohort received PS TKAs, the weak correlations observed are unsurprising. It can be suggested that the inherent design features of the PS TKA prevent anterior translation of the femur during flexion delaying

Table 3
Preoperative and postoperative patient-reported outcome measures, presented as mean ± standard deviation.

Time point/PROM	GB (n = 129)	MR (n = 191)	*P* value
Preoperative			
SF-12 MCS	51.9 ± 11.3	54.5 ± 10.9	.05
SF-12 PCS	31.2 ± 7.59	31.6 ± 8.36	.95
WOMAC total	47.1 ± 16.2	47.8 ± 14.5	.50
KSS total score	94.2 ± 24.9	88.9 ± 20.8	.36
Postoperative			
SF-12 MCS	53.9 ± 9.17	55.1 ± 9.76	.12
SF-12 PCS	40.2 ± 10.9	42.0 ± 11.0	.12
WOMAC total	78.3 ± 17.9	80.9 ± 15.8	.08
KSS total score	169 ± 26.2	175 ± 25.3	.34

MCS, mental component score; PCS, physical component score.

the posterior impingement [5]. This can be compared to CR TKAs which rely upon normal posterior cruciate ligament function and PCO to ideally maintain normal knee kinematics. Thus, when PCO is modified in CR TKAs, flexion limitations are more likely to manifest, as an increased PCO in a CR knee can result in an overly tight posterior cruciate ligament and pathologic knee mechanics. While the post-cam mechanism in PS TKAs acts as a preventative strategy for flexion limitation associated with PCO. It is important to note that a recent study conducted by Chang et al. did not report a significant correlation between postoperative PCO and postoperative ROM [8]. That study, however, examined 184 knees from 130 consecutive patients and primarily focused on differences between anterior- and posterior-referencing systems for measuring PCO. We believe the reason that we observed a significant correlation between these measures, and they did not, is based on the total number of knees included in the analysis.

A study of 89 knees examined the correlation between change in PCO and WOMAC and KSS scores [21] and found no correlation between any WOMAC or KSS subscore. We also observed no significant correlations between PCO change and WOMAC and KSS subscores. This corroboration is important to note as the prior study involved only 89 knees, whereas our study included 498 knees. We, however, did observe a significant correlation between the KSS knee ROM subscore and KSS total with postoperative PCO. The lack of correlation between WOMAC subscores and total score with postoperative PCO may be due to the disease-specific nature of the questionnaire. The KSS is a joint-specific questionnaire and is therefore more specific and sensitive to joint-specific parameters.

All patients reported significant improvement in the SF-12 physical component score, the WOMAC, and the KSS score postoperatively. The improvement in score was not dependent on surgical technique. This is consistent with current literature.

The strength of this study lies in its large sample size. We were able to examine the impact of PCO in a population of approximately 500 TKAs performed by fellowship-trained arthroplasty surgeons. Future studies could examine the impact of PCO in CR TKA populations as our study population was composed of predominantly PS TKA designs.

Our study demonstrated that there was no significant impact of surgical technique on postoperative PCO measures. As such, surgeons should use the technique they are most comfortable with and that most suitable to the specific patient. Furthermore, the results of our study demonstrated that patient improvement compared with preoperative measures can be expected regardless of surgical technique and postoperative PCO. Nonetheless, the weak, albeit significant, correlation observed between postoperative PCO and 1-year joint ROM should provide encouragement to surgeons to maximize patient PCO postoperatively with the goal of maximizing their long-term ROM.

Conclusions

This study found no significant impact of a GB or MR surgical technique on postoperative PCO. Significant correlation was observed between increased magnitude of postoperative PCO and improved flexion component and total score of the knee-specific KSS questionnaire.

Conflicts of interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: M. G. Teeter has stock or stock options in IdealFit Spacer Technologies and is a board member of the International Society for Technology in Arthroplasty and Canadian RSA Network. J. L. Howard is in the speakers' bureau of/gave paid presentations for DePuy, Stryker, Smith & Nephew, and IntelliJoint; is a paid consultant for Stryker, Smith & Nephew, DePuy, and IntelliJoint; has stock or stock options in PersaFix Technologies; received research support as a principal investigator from DePuy; received financial or material support and institutional research support from DePuy, Smith & Nephew, Stryker, Zimmer, and Microport. L. E. Somerville received financial or material support and institutional research support form Smith & Nephew, DePuy, Stryker, and Zimmer. B. A. Lanting is a paid consultant for Stryker, Smith & Nephew, DePuy, and IntelliJoint; has stock or stock options in PersaFix Revision and IdealFit Spacer Technologies; received research support as a principal investigator from Smith & Nephew, DePuy, and Stryker; received financial or material support and institutional research support from Smith & Nephew, DePuy, and Stryker.

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